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(54) Lightweight concrete roof tiles.

(57) Lightweight concrete roof tiles are produced using a cement/lightweight aggregate/water mix containing a non-thixotropic silica fume in a weight ratio of silica fume (calculated as dry weight) to cement of about 2:98 to about 25:75, preferably about 8:92 to about 12:88. A dispersing agent for the silica fume is included in the mix. The presence of non-thixotropic silica fume in the mix enables lightweight roof tiles of adequate flexural strength to be produced. Novel roof tiles and novel cement/lightweight aggregate/water mixes for use in the method are also described.

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Lightweight concrete roof tiles

This invention relates to the production  
5 of concrete roof tiles by the well-known roller  
and slipper method and is particularly concerned  
with such a method of production which provides  
lightweight concrete roof tiles of a kind which  
are for example useful as a replacement for wood  
10 shingles and shakes, asphalt shingles, asbestos  
cement roofing, slates, etc.

It is well known to produce concrete roof  
tiles by the so-called roller and slipper method  
wherein the tile forming material which usually  
15 consists of a mix of cement, sand and water is  
compressed on to moving pallets first by means  
of a roller and then by means of a slipper. The  
ribbon of tile forming material thereby obtained,  
which is conventionally referred to as the extrudate,  
20 is then cut into sections of the required length  
and cured e.g. at elevated temperatures under conditions  
of high humidity to produce the finished roof tiles.  
A description of the conventional apparatus which  
has for many years been used in the commercial  
25 production of concrete roof tiles by the roller  
and slipper method is for example included in PCT  
International Publication No. WO 85/00135.

Roof tiles of essentially flat and of convoluted  
constructions are routinely made by the roller  
30 and slipper method and typically have densities  
of from 2.1 to 2.2 g/cc. Interlocking roof tiles  
having the usual dimensions for the United Kingdom  
of about 413 mm length x 330 mm width x 11.5 to  
12.5 mm thickness and for the United States of  
35 America of about 422mm length x 333mm width x 11.5  
to 12.5mm thickness generally have a weight in  
the range of from 4.2 to 5.0 kg per tile, streng-  
thening ribs, nibs and weatherchecks which are

provided on the undersides of concrete interlocking roof tiles adding to the overall weight.

It is recognised that concrete roof tiles of the kind described above provide a satisfactory and highly durable roofing material and they are extensively used for the roofing of new houses and other buildings. For re-roofing, however, there is frequently a problem in that the roofing material to be replaced may be a lighter weight roofing material such as for example wood shingles and shakes, asphalt shingles, asbestos cement roofing, slates, etc. and the building concerned may be incapable of bearing the additional load which would result from re-roofing with conventional concrete roof tiles. Thus, for example, with timber framed buildings, it may be necessary to reinforce the existing roof timbers to ensure that they will bear the additional load. This is costly and in practice often results in a decision not to utilise concrete roof tiles for re-roofing work.

There is thus a need for a concrete roof tile which is lighter in weight than conventional concrete roof tiles of the kind described above but which has adequate strength and durability whereby it is suitable for use as a replacement for wood shingles and shakes, asphalt shingles, asbestos cement roofing, slates, etc.

It is known that the weight of concrete can be reduced by the use of lightweight aggregates as a partial or complete substitute for sand. Numerous lightweight aggregates have been proposed for this purpose including naturally occurring materials such as pumice and scoria and materials produced by manufacturing processes such as sintered pulverised fuel ash (e.g. available as Lytag from Pozzolan-Lytag Limited of Hemel Hempstead, Hertfordshire, England) and expanded materials such as expanded clay, shale, slate, vermiculite and perlite. In

- general, however, the use of such lightweight aggregates in order to obtain a lower weight concrete results in a reduction in flexural strength and consequently, in order to obtain a concrete roof tile of adequate
- 5 flexural strength, it is necessary to increase the thickness of the tiles made of such lightweight concrete as compared with that of a conventional concrete roof tile to such an extent that no worthwhile weight advantage is achieved.
- 10 It is an object of the present invention to provide a method of producing concrete roof tiles which are substantially lighter in weight than conventional concrete roof tiles but which have comparable flexural strength.
- 15 Another problem which has arisen in attempting to produce concrete roof tiles by the roller and slipper method using lightweight aggregates as a substitute for sand is caused by the consequent change in the rheological properties of the mix.
- 20 In order to produce a satisfactory concrete roof tile by the roller and slipper method, it is important that the mix should flow evenly during extrusion, i.e. during compression first between the pallets and the roller and then during further compression
- 25 between the pallets and the slipper, as otherwise there are likely to be difficulties with uneven compaction, rough and open surfaces on the wear side of the tiles and poor definition of interlocks, upstands, nibs and weatherchecks on the under side
- 30 of the tiles. Also the mix must have a sufficient degree of cohesion so that cracks do not form in the extrudate, e.g. upon cutting into sections of the required length for use as roof tiles. While it may be possible to improve the cohesion
- 35 of the extrudate by increasing the amount of water in the mix, this may also result in a greater tendency for the mix to adhere to the equipment with which it comes into contact during the manufacturing

process, e.g. the blades and sides of the mixer, conveyor belting, the roller, the slipper, etc. Also the use of wetter mixes can result in slumping of the extruded tiles, for example upon cutting  
5 and when they are in the process of being transferred to a curing chamber. While conventional cement/sand/water mixes having satisfactory properties for use in the roller and slipper method can be prepared, it has been found that the replacement of sand  
10 by lightweight aggregates modifies the rheology of the mix and that the correct balance of properties which is essential to the production of a satisfactory extruded concrete roof tile is no longer attainable. This has led to the proposal to replace only part  
15 of the sand used in the conventional mix by lightweight aggregate, thereby achieving a mix having a balance of rheological properties closer to that of a conventional cement/sand/water mix, but this leads to a reduction in the weight advantage.

20 It has been proposed to incorporate fine particle size silica in cement/aggregate/water mixes for use in the production of concrete products including lightweight concrete products, see for example US 3 232 777 (Bush), US 3 880 664 (Schulze),  
25 US 4 087 285 (Kurz) and PCT International Publication No. WO 80/00959. The presence of fine particle size silica in such mixes modifies the rheological properties thereof by increasing the flowability. Thus US 3 880 664 (Schulze) refers to the addition  
30 of small amounts of fumed silica as being most advantageous to certain types of extrusion (col. 4, lines 16-18) and to the fumed silica adding universal and superior extrudability qualities (col 4, line 22), the silica fume used being highly thixotropic  
35 and the mix being very fluid and pliable (col 4, lines 37-38). There is also reference in US 3 880 664 (Schulze) to the use of a greatly increased percentage of water in conjunction with the fumed silica where

it is particularly desired to make lightweight products (col. 5, lines 7-10). PCT International Publication No. WO 80/00959 also describes the use of readily flowable mixes (see for example  
5 p. 9, line 23; p 24, lines 20-25; page 27, lines 12-21) and it can be seen from the consistency test described at page 64, line 28 to page 65, line 3 that the mixes have a strong tendency to slump after shaping.

10 The readily flowable mixes described in the above-mentioned publications are unsuitable for use in the roller and slipper method for the production of concrete roof tiles, for which it is essential  
15 that the mix be non-pourable with a low tendency to slump after shaping. Thus, in contrast to the mixes tested for consistency in PCT International Publication No. WO 80/00959, mixes suitable for use in the roller and slipper method for producing concrete roof tiles need to give diameter measurements  
20 of not more than about 10.5 cms when evaluated in accordance with British Standard No. 4551 by measuring the spreading of a core of the mix formed by introducing the mix into a  $5.08 \pm 0.05$  cm high brass core mould with bottom internal diameter of  
25  $10.16 \pm 0.05$  cms and upper internal diameter of  $6.99 \pm 0.05$  cm on a flow table with brass surface, removing the mould and subjecting the flow table to 25 drops (i.e. strokes). The mix must also have good cohesivity whereby, when subjected to  
30 the above consistency test, no cracks visible to the naked eye are apparent in the shaped material. Prior to the present invention, it was to be expected that the incorporation of silica fume in mixes for use in the roller and slipper method for producing  
35 lightweight concrete roof tiles would result in an undesired increase in flowability and tendency for the extrudate to slump after shaping and that it would be impossible to compensate e.g. by reducing the amount of water in the mix without adversely affecting the cohesivity

of the mix.

It is a further object of the present invention to provide a cement/lightweight aggregate/water mix which contains silica fume and which has advantageous  
5 properties for use in the roller and slipper method for the production of lightweight concrete roof tiles of good flexural strength.

The present invention is based upon the surprising discovery that a non-thixotropic silica fume can  
10 be incorporated into cement/lightweight aggregate/water mixes to provide such mixes having advantageous properties for use in the production of concrete roof tiles by the roller and slipper method and that very satisfactory lightweight concrete roof  
15 tiles of good flexural strength can thereby be produced.

According to one feature of the present invention, there is thus provided a method of producing concrete roof tiles in which a cement/aggregate/water mix  
20 is shaped by the roller and slipper method, the shaped extrudate thereby obtained is divided to form sections and the sections are cured; the aggregate in the said mix comprising lightweight aggregate, the said mix additionally containing a non-thixotropic  
25 silica fume in a weight ratio of silica fume (calculated as dry weight) to cement within the range of from about 2:98 to about 25:75 and a dispersing agent for the said silica fume, and the weight ratio of water: cementitious materials in the said mix  
30 being within the range of from about 0.45:1 to about 1:1 whereby the said mix is shaped, the extrudate divided and the sections cured to form lightweight concrete roof tiles.

According to a further feature of the present  
35 invention there is provided a lightweight concrete roof tile which has been produced by the roller and slipper method and which contains the reaction products of a non-thixotropic silica fume with

lime; said tile having a density of from about 1.2 to about 1.6 g/cc and said reaction products contributing to the flexural strength of the tile.

According to a still further feature of the  
5 present invention there is provided a cement/aggregate/water mix for use in the production of concrete roof tiles by the roller and slipper method; the aggregate in the said mix comprising lightweight aggregate, the said mix additionally containing a non-thixotropic  
10 silica fume in a weight ratio of silica fume (calculated as dry weight) to cement within the range of from about 2:98 to about 25:75 and a dispersing agent for the said silica fume, and the weight ratio of water: cementitious materials in the said mix  
15 being within the range of from about 0.45:1 to about 1:1 whereby the said mix is shapable by the roller and slipper method to provide an extrudate for division and curing to form lightweight concrete roof tiles.

20 Silica fumes are known materials which can be thixotropic or non-thixotropic according to the method used for their preparation. Thixotropic silica fumes in general comprise spherical silica particles fused together to form branched chains.  
25 When mixed with water the oxygen atoms of the silica particles enter into hydrogen bonding with the hydrogen atoms of the water molecules. In this way the water molecules become bound to the branched silica chains so that the mixture is highly viscous  
30 and thixotropic. An example of a thixotropic silica fume is the product "Cab-O-Sil" as referred to in US 3880664 (Schulze), this product being prepared by a vapour phase process involving the hydrolysis of silicon tetrachloride at about 1100°C. "Cab-  
35 O-Sil" is highly thixotropic with 10%, 22% and 33% by weight mixtures with water giving a gel, a sticky powder and a free-flowing powder respectively.



The expression 'non-thixotropic silica fume' is used herein to define silica fumes which in the form of a 50% by weight mixture with water give a free flowing liquid slurry. In non-thixotropic

- 5 silica fumes there is no significant degree of fusion of silica particles to form branched chains and when mixed with water such non-thixotropic silica fumes do not give rise to any significant amount of thixotropy in the mixture obtained.
- 10 Thus, when incorporated into cement mixes for use in the production of concrete products, thixotropic silica fumes and non-thixotropic silica fumes perform very different functions.

- One known method of producing non-thixotropic
- 15 silica fumes is as a by-product in electric arc furnaces used for the production of silicon metal and ferrosilicon alloys. At the high temperatures reached in the formation of silicon metal and ferrosilicon alloys, silicon monoxide gas is formed by the reduction
- 20 of quartz and is then re-oxidised to silica at the lower temperatures above the charge. The silica thereby obtained is condensed as fume and can be recovered by filtration. The non-thixotropic silica fume obtained consists of extremely fine, essentially
- 25 spherical particles of amorphous silica, the mean average particle size typically being in the range of from about 0.05 to about 0.15 micrometer, e.g. about 0.1 micrometer, and the surface area typically being in the range of from about 15 to about 25 m<sup>2</sup>/g,
- 30 e.g. about 20 m<sup>2</sup>/g. The exact chemical composition of the non-thixotropic silica fume can vary somewhat according to the precise method of production and for example three grades of non-thixotropic silica fume are available as ELKEM SILICA 100, ELKEM SILICA
- 35 90 and ELKEM SILICA 75 from Elkem Chemicals of Pittsburgh, Pennsylvania, U.S.A. In general any of these grades of non-thixotropic silica fume, all of which have a high silica content within

the range of from 85 to 98% by weight, is suitable for use in the present invention.

In order to prepare cement/lightweight concrete/ water mixes according to the invention having advantageous properties for the purpose of producing concrete roof tiles by the roller and slipper method, it is desirable to incorporate the non-thixotropic silica fume into the mix in admixture with an effective amount of a dispersing agent therefor. Suitable dispersing agents include lignosulfonates, naphthalene sulfonate superplasticisers and melamine-formaldehyde superplasticisers, examples of such dispersing agents being CORMIX P1 lignosulfonate dispersing agent available from Cormix Limited, Warrington, Cheshire, England, CORMIX SP1 naphthalene sulfonate superplasticiser also available from Cormix Limited and MELMENT L10 melamine-formaldehyde superplasticiser available from Hoechst UK Limited of Hounslow, Middlesex, England. Where for example a lignosulfonate dispersing agent is used, the amount of dispersing agent is conveniently within the range of from about 2.0 to about 5.0% based upon the dry weight of the non-thixotropic silica fume. Where a superplasticiser is used, the amount calculated on a dry weight basis of naphthalene sulfonate or other superplasticiser is preferably in the range of from about 0.2 to about 5.0% based upon the weight of cementitious materials in the mix. The dispersing agent and the non-thixotropic silica fume are conveniently combined in the form of an aqueous slurry, for example containing the silica fume and water in a ratio of about 1:1 by weight. Silica fume/dispersing agent mixes are sometimes referred to as plasticised silica fumes and one such product suitable for use in the present invention is that available as EMSAC F110 from Elkem Chemicals.

The amount of non-thixotropic silica fume incorporated into the cement/lightweight aggregate/water

mix should be effective to improve the flexural strength of the roof tiles obtained. It has been found that the use of weight ratios of non-thixotropic silica fume (calculated as dry weight) to cement  
5 of about 2:98 to about 25:75, more preferably about 6:94 to about 12:88 and still more preferably about 8:92 to about 12:88, provides a very substantial improvement in the flexural strength of the roof tiles obtained. Moreover, and very surprising  
10 having regard to the critical balance of properties required when extruding cement/lightweight aggregate/water mixes by the roller and slipper method it has been found possible to provide mixes containing such amounts of non-thixotropic silica fume which have  
15 advantageous properties for use in the roller and slipper method.

As stated above, available lightweight aggregates include naturally occurring materials such as pumice and scoria and materials produced by manufacturing  
20 processes such as sintered pulverised fuel ash and expanded materials such as expanded clay, shale, slate, vermiculite and perlite. In selecting the lightweight aggregate, it is important that the material concerned in combination with the other  
25 ingredients shall give a mix having the best possible properties for use in the roller and slipper method. It has been found that expanded clay aggregate is particularly suitable for this purpose. While the simple substitution of sand in a conventional  
30 cement/sand/water mix by an equal volume of expanded clay aggregate provides a mix with very poor rheological properties not at all suitable for extrusion to produce satisfactory roof tiles, it has surprisingly been found that the use of expanded clay as lightweight  
35 aggregate in mixes according to the invention which contain plasticised non-thixotropic silica fume provides mixes having very advantageous rheological properties. Using such mixes, it has been found possible by the method of the invention to produce

well compacted tiles with a satisfactory smooth wear surface and with clearly defined interlocks, upstands, nibs and weatherchecks. Advantages which have been observed using expanded clay as lightweight aggregate in mixes according to the invention thus include the avoidance of any significant tendency for the extruded tiles to slump, for example upon cutting or when they are in the process of being transferred to a curing chamber; reduction of the common problem of abrasion of the slipper as a result of contact with the mix with consequent deterioration in the surface appearance of the tiles, the use of the mixes according to the invention having the beneficial effect of polishing the surface of the slipper thereby resulting in an improvement in the surface appearance of the tiles; and the possibility of extruding at lower pressures as a result of the advantageous rheological properties of the mixes according to the invention thereby reducing wear on the extruder.

The expanded clay which is preferably used in accordance with the invention is a sand-grade material, i.e. has a particle size of less than about 4.75 mm, and advantageously has a particle size distribution approximating to that of the sand used in conventional mixes for the production of concrete roof tiles by extrusion. Expanded clay aggregate meeting these requirements can be produced by an extrusion and chopping method.

Fine sand-grade material having a particle size of less than about 3.35 mm is particularly preferred and one such material having a suitable particle size distribution is that available as RIDGELITE No. 3 FINE SAND from Lightweight Processing Co. of Glendale, California, U.S.A.

Other lightweight aggregate materials may be used instead of expanded clay, dependant however upon the availability of appropriate grades of

such materials. One such material is expanded shale. Examples of other such materials are sintered pulverised fuel ash and pumice. Again sand-grades of these materials, having a particle size of less  
5 than about 4.75 mm and advantageously particle size distributions similar to that of the sand used in conventional mixes, are preferably used.

The ratio by weight of lightweight aggregate to cementitious materials (including the cement  
10 and the silica fume) is preferably in the range of about 1:1 to about 3:1, more preferably about 1.5:1 to about 2.5:1. In general, the lighter the aggregate the lower will be the weight ratio of aggregate to cementitious materials. Where  
15 for example expanded clay is used as the lightweight aggregate, the weight ratio of expanded clay to cementitious materials is preferably about 2:1.

The cement used in the method according to the invention is conveniently ordinary Portland  
20 cement which is mixed with the lightweight aggregate, the non-thixotropic silica fume and dispersing agent therefor (preferably in the form of a plasticised non-thixotropic silica fume slurry) and water to form the mix. The amount of water required in  
25 order to obtain a mix of suitable consistency will in general be greater than that required for conventional mixes which contain sand as aggregate due to the porous character of most lightweight aggregates but need not be greatly increased. Thus the amount  
30 of water in the mix is preferably from about 12 to about 24% by weight, for example about 16 to about 19% by weight. The weight ratio of water: cementitious materials is in general in the range of from about 0.45:1 to about 1:1, preferably from  
35 about 0.6:1 to about 0.8:1. It will be appreciated that the amount of water as well as the amounts of non-thixotropic silica fume and dispersing agent therefor are selected to provide a mix having the

desired consistency for use in the roller and slipper method, such mixes being non-pourable and having a low tendency to slump after shaping. The mixes for use in the method according to the present invention should thus be formulated to give a diameter measurement of not more than about 10.5 cms when evaluated by the consistency test in accordance with BS 4551 as hereinbefore described and should have good cohesivity whereby when subjected to the said consistency test, no cracks visible to the naked eye are apparent in the shaped material.

Pigments may be incorporated in the mix in order to provide roof tiles of the desired colour. The mix is extruded, cut and cured in accordance with the well-known roller and slipper method, curing conveniently being carried out at temperatures of from 35°C to 65°C, preferably about 50°C, for at least 8 hours, preferably from 12 to 24 hours, under conditions of high humidity. Whilst it is not desired to be restricted by any theoretical explanation for the working of the invention, it is believed that during curing an additional chemical reaction takes place between the silica fume and lime released as a result of the hydration of the cement and that the calcium silicate hydrates thereby formed contribute to the strength of the roof tiles produced.

It has been possible using a method according to the invention to produce concrete roof tiles having densities of from about 1.2 to about 1.6 g/cc, for example about 1.3 to about 1.5 g/cc, and having a weight per tile down to about 55% of the weight of conventional concrete roof tiles but with comparable flexural strength. Because of the improvement in flexural strength resulting from the presence of the reaction products of plasticised non-thixotropic silica fume and lime, the desired flexural strength is obtained with reduced thicknesses

as compared with the usual thickness for conventional roof tiles and the reduction in thickness as well as the lightweight aggregate contribute to the overall up to 45% reduction in the weight of the  
5 tile. The tiles in accordance with the present invention preferably have a minimum thickness (excluding interlocks which are generally thinner than the main body of the tile) of from about 9 to about 12 mm, particularly about 10 to about 11 mm. The  
10 flexural strength (i.e. average breaking load) of the tiles according to the invention when measured in Newtons (N) in accordance with British Standard No. 473550 is preferably as follows:

- 15 a) flat interlocking (i.e. single lap) tiles, not less than about 3.2. times and more preferably not less than about 4.0 times the effective width of the tiles in millimetres,
- 20 b) for convoluted interlocking (i.e. single lap) tiles, not less than about 3.2 times and more preferably not less than about 5.0 times the effective width of the tiles in millimetres,
- 25 c) for plane tiles at least about 490 N and more preferably at least about 600 N and
- 30 d) for double lap tiles, not less than about 2.1 times the effective width of the tiles.

Thus, for example, with interlocking (i.e. single lap) tiles having the usual dimensions for the United States of America of about 422 mm length  
35 x 333 mm width x 11.5 to 12.5 mm thickness, the flexural strength for flat tiles is advantageously at least about 1200 N and for convoluted tiles at least about 1600 N.

The following examples illustrate the invention:

EXAMPLE 1

909 kg of moist RIDGELITE No 3 FINE SAND  
5 (water content of about 18% by weight), 335 kg  
of Portland cement, 82.7 kg of EMSAC F110 and 13 kg  
of a synthetic red oxide pigment were mixed in  
a rotary pan mixer with sufficient water to provide  
an extrudable mix containing about 18% by weight  
10 of water. The mix was used to extrude concrete  
roof tiles on metal pallets by the well-known roller  
and slipper method, the settings on the extruder  
(i.e. the box) being adjusted to provide a tile  
thickness of about 10.5 mm. On extrusion, it was  
15 found that good quality convoluted interlocking  
tiles were formed with a satisfactorily smooth  
surface, well formed and defined interlocks and  
well filled and formed nibs and weatherchecks on  
the bottom surface of the tiles. Approximately  
20 420 tiles of dimensions 422 mm x 333 mm x about  
10.5 mm were made from this mix. These tiles were  
transported to curing cabinets where they were  
cured at 50°C and 95 - 100% Relative Humidity for  
a period of 10 hours. After curing, the tiles  
25 were removed from the metal pallets and allowed  
to stand in stacks in the open for a period of  
7 days. Sample tiles were then selected at random,  
weighed and tested for flexural strength by the  
method specified in British Standard No. 473550.

30

Average weight per tile - 2.72 kg  
Average flexural strength - 2070 N

EXAMPLE 2 (for comparison)

35 1227 kg of damp silica sand (water content  
of about 3% by weight), 373 kg Portland cement  
and 13 kg of a synthetic red oxide pigment were  
mixed in a rotary pan mixer with sufficient water



to provide an extrudable mix containing about 9% by weight water. The mix was used to extrude concrete roof tiles on metal pallets as in Example 1, the settings on the extruder (i.e. the box) being adjusted to provide a tile thickness of about 12 mm. On extrusion, it was found that good quality convoluted interlocking tiles were made, with a satisfactorily smooth surface, well formed and defined interlocks and well filled nibs and weatherchecks on the bottom surface of the tiles. Approximately 360 tiles, of dimensions 422 mm x 333 mm x about 12 mm and of the same convoluted shape as the tiles in Example 1, were made from this mix. These tiles were transported to curing cabinets where they were cured at 50°C and 95 - 100% Relative Humidity for a period of 10 hours. After curing, the tiles were removed from the metal pallets and allowed to stand in stacks in the open for a period of 7 days. Sample tiles were then selected at random, weighed and tested for flexural strength by the method specified in British Standard No. 473550. The results obtained were as follows:-

	Average weight per tile	-	4.60 kg
25	Average flexural strength	-	2100 N

### EXAMPLE 3 (for comparison)

909 kg of moist RIDGELITE No. 3 FINE SAND (water content of about 18% by weight), 373 kg of Portland cement and 13 kg of a synthetic red oxide pigment were mixed in a rotary pan mixer with sufficient water to provide an extrudable mix containing about 18% by weight of water. The mix was used to extrude concrete roof tiles on metal pallets as in Example 1, the settings on the extruder (i.e. the box) being adjusted to provide a tile thickness of about 10.5 mm. On extrusion it was found that the tiles could not be satisfactorily

formed and that they exhibited a rough and 'open' surface texture, highly feathered and broken interlocks and incomplete filling of the nib and weathercheck sections on the bottom surface of the tiles. Attempts  
5 to repeat the above but using different levels of water addition were unsuccessful and no tiles were of sufficiently satisfactory quality for strength tests to be carried out.

A comparison of Example 1 in accordance with  
10 the present invention and Example 2 in accordance with conventional practice shows that it is possible by means of the present invention to produce concrete roof tiles which have substantially the same flexural strength as those produced by a conventional method  
15 but which have a reduced thickness and a weight which is only about 60% of that of tiles produced by the conventional method.

A comparison of Example 1 in accordance with the present invention and Example 3 in which the  
20 same lightweight aggregate is used but without the presence of silica fume shows the advantage which is provided by the use of a cementitious mixture containing silica fume and cement in a weight ratio of about 1:9 as compared with the  
25 use of cement alone as the cementitious material.

#### EXAMPLE 4

636 kg of moist Baypor sand (an expanded shale having a water content of about 11% by weight  
30 available from Port Costa Materials Inc of Port Costa, California, USA), 273 kg of Portland cement, 67 kg of EMSAC F110 and 10 kg of a synthetic red oxide pigment were mixed in a rotary pan mixer with sufficient water to provide an extrudable  
35 mix containing about 15% by weight of water. The mix was used to extrude concrete roof tiles on metal pallets by the well-known roller and slipper method, the settings on the extruder (i.e. the

box) being adjusted to provide a tile thickness of about 10.5 mm. On extrusion it was found that good quality convoluted interlocking tiles were formed with a satisfactory smooth surface, well  
5 formed and defined interlocks and well filled and formed nibs and weatherchecks on the bottom surface of the tiles. Approximately 285 tiles of dimensions 422 mm x 333 mm x about 11 mm were made from this mix. These tiles were transported to curing cabinets  
10 where they were cured at 50°C and 95-100% Relative Humidity for a period of 12 hours. After curing, the tiles were removed from the metal pallets and allowed to stand in stacks in the open for a period of 7 days. Sample tiles were then selected at  
15 random, weighed and tested for flexural strength by the method specified in British Standard No. 473550.

Average weight per tile - 3.44 kg  
20 Average flexural strength - 2192 N

EXAMPLE 5

510 kg of moist Baypor sand (having a water content of about 7% by weight), 227 kg of Portland cement, 25 kg of Corrochem (a dry non-thixotropic silica fume available from Scancem, Slemmestad, Norway incorporating a naphthalene sulphonate super-plasticizer) and 10 kg of a synthetic red oxide pigment were mixed in a rotary pan mixer with sufficient water to provide an extrudable mix containing about 16% by weight of water. The mix was used to extrude concrete roof tiles on to metal pallets by the roller and slipper method, the settings on the extruder (i.e. the box) being adjusted to provide a tile thickness of around 11.0 mm. On extrusion it was found that good quality convoluted interlocking tiles were formed with a satisfactory smooth surface, well formed and defined interlocks and well filled and formed ribs and weatherchecks on the bottom surface of the tiles. Approximately 250 tiles of dimensions 422 mm x 333 mm x about 11 mm were made from the mix. These tiles were transported to curing cabinets where they were cured at 44°C and 95-100% Relative Humidity for a period of 8 hours. After curing, the tiles were removed from the metal pallets and allowed to stand in stacks in the open for a period of 7 days. Sample tiles were then selected at random, weighed and tested for flexural strength by the method specified in British Standard No. 473,550.

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Average weight per tile - 3.08 kg

Average flexural strength - 1630 N

35 EXAMPLE 6

360 kg of moist Lytag fine grade aggregate (a sintered pulverized fuel ash having a water content of about 5% by weight, available from Pozzolan-Lytag

Limited of Hemel Hempstead, Hertfordshire, England),  
172 kg of Portland cement, 35 kg of EMSAC F110 and  
10 kg of a synthetic red oxide pigment were mixed  
in a rotary pan mixer with sufficient water to  
5 provide an extrudable mix containing about 14%  
by weight of water. The mix was used to extrude  
concrete roof tiles on to metal pallets by the roller  
and slipper method, the settings on the extruder  
(i.e. the box) being adjusted to provide a tile  
10 thickness of about 11 mm. On extrusion it was  
found that good quality convoluted interlocking  
tiles were formed with a satisfactory smooth surface,  
well formed and defined interlocks and well filled  
and formed ribs and weatherchecks on the bottom  
15 surface of the tiles. Approximately 260 tiles  
of dimensions 380 mm x 230 mm x about 11 mm were  
made from the mix. The tiles were transported  
to curing cabinets where they were cured at 42°C  
and 95-100% Relative Humidity for a period of 15  
20 hours. After curing, the tiles were removed from  
the metal pallets and allowed to stand in stacks  
in the open for a period of 7 days. Sample tiles  
were then selected at random, weighed and tested  
for flexural strength by the method specified in  
25 British Standard No. 473,550.

Average weight per tile - 2.24 kg

Average flexural strength - 1248 N

Claims

1. A method of producing concrete roof tiles in which a cement/aggregate/water mix is shaped by the roller and slipper method, the shaped extrudate thereby obtained is divided to form sections and  
5 the sections are cured; the aggregate in the said mix comprising lightweight aggregate, the said mix additionally containing a non-thixotropic silica fume in a weight ratio of silica fume (calculated as dry weight) to cement within the range of from  
10 about 2:98 to about 25:75 and a dispersing agent for the said silica fume, and the weight ratio of water: cementitious materials in the said mix being within the range of from about 0.45:1 to about 1:1 whereby the said mix is shaped, the extrudate  
15 divided and the sections cured to form lightweight concrete roof tiles.
2. A method according to claim 1 wherein the silica fume is a by-product of an electric arc furnace process for the production of silicon metal  
20 and ferrosilicon alloys.
3. A method according to claim 1 or claim 2 wherein the silica fume has a mean average particle size in the range of from about 0.05 to about 0.15 micrometer and a surface area in the range of from  
25 about 15 to about 25 m<sup>2</sup>/g.
4. A method according to any of the preceding claims wherein the lightweight aggregate comprises a sand-grade expanded clay or sand-grade expanded shale having a particle size of less than about 4.75 mm.
- 30 5. A method according to claim 4 wherein the particle size is less than about 3.35 mm.
6. A method according to any of the preceding claims wherein the weight ratio of non-thixotropic silica fume (calculated as dry weight) to cement  
35 is from about 8:92 to about 12:88.

7. A method according to any of the preceding claims wherein the weight ratio of water: cementitious materials in said mix is in the range of from about 0.6:1 to about 0.8:1.
- 5 8. A method according to any of the preceding claims wherein the dispersing agent is a lignosulfonate dispersing agent.
9. A method according to claim 8 wherein the mix contains an amount of the lignosulfonate dispersing agent within the range of from about 2.0 to about 5.0% based upon the dry weight of the silica fume.
- 10 10. A method according to any of claims 1 to 7 wherein the dispersing agent is a naphthalene sulfonate superplasticiser.
- 15 11. A method according to claim 10 wherein the mix contains the naphthalene sulfonate superplasticiser in an amount calculated on a dry weight basis of from about 0.2 to about 5.0% based upon the weight of cementitious materials in the mix.
- 20 12. A method according to claim 11 wherein said amount of naphthalene sulfonate superplasticiser is from 0.75 to 3.0%.
13. A method of producing lightweight concrete roof tiles substantially as herein described in
- 25 Example 1 or Example 4.
14. A lightweight concrete roof tile which has been produced by the roller and slipper method and which contains the reaction products of a non-thixotropic silica fume with lime; said tile having
- 30 a density of from about 1.2 to about 1.6 g/cc and said reaction products contributing to the flexural strength of the tile.
15. A lightweight concrete roof tile when produced by a method as claimed in any of claims 1 to 13.
- 35 16. A roof tile according to either of claims 14 and 15 having a density of from about 1.3 to about 1.5 g/cc.

17. A cement/aggregate/water mix for use in the production of concrete roof tiles by the roller and slipper method; the aggregate in the said mix comprising lightweight aggregate, the said mix
- 5 additionally containing a non-thixotropic silica fume in a weight ratio of silica fume (calculated as dry weight) to cement within the range of from about 2:98 to about 25:75 and a dispersing agent for the said silica fume, and the weight ratio
- 10 of water: cementitious materials in the said mix being within the range of from about 0.45:1 to about 1:1 whereby the said mix is shapable by the roller and slipper method to provide an extrudate for division and curing to form lightweight concrete
- 15 roof tiles.





European Patent  
Office

# EUROPEAN SEARCH REPORT

0173553

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 85306036.6
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl 4)
Y	US - A - 3 677 686 (POWEL) * Page 1, lines 3-21 * --	1,2,3, 6,13, 14,17	B 28 B 1/29 C 04 B 18/06 //C 04 B 18/14
Y	US - A - 4 384 896 (AITCIN) * Column 1, line 12; column 2, lines 51-54 * --	1,2,3, 6,13, 14,17	
A	US - A - 4 310 486 (CORNWELL) * Column 1, lines 12-28 * ----	1,2,4, 13,14, 17	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl 4)
			B 28 B C 04 B
Place of search VIENNA		Date of completion of the search 18-11-1985	Examiner GLAUNACH
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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